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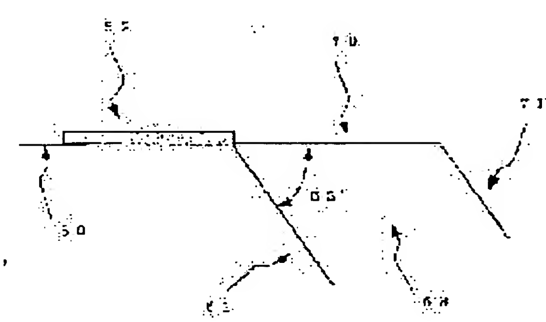
(54) SEMICONDUCTOR DEVICE AND ITS MANUFACTURING METHOD, AND METHOD FOR MANUFACTURING SEMICONDUCTOR SUBSTRATE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a semiconductor device having improved photoelectric characteristics by improving the flatness at an atom level and hence improving the steepness in an interface.
SOLUTION: The semiconductor device comprises a silicon substrate and a compound semiconductor layer that is formed on the main surface of the silicon substrate and is expressed by a general expression InxGayAlzN (in this case, x+y+z=1, 0≤x≤1, 0≤y≤1, 0≤z≤1). The silicon substrate has a groove having, as an inclined surface, a surface that is inclined by 62 degrees from the main surface of the silicon substrate, or a surface that is inclined within 3 degrees in an arbitrary direction from the surface. The compound semiconductor layer is formed on the inclined surface.



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CLAIMS

[Claim(s)]
[Claim 1] The general formula InxGayAlzN formed on the principal plane of a silicon substrate and said silicon substrate It is the semiconductor device which has the compound semiconductor layer expressed with (x+y+z=1, 0<=x<=1, 0<=y<=1, 0<=z<=1). Said silicon substrate [however,] the principal plane of said silicon substrate -- the sloping field of 62 degrees -- or the semiconductor device characterized by having the slot which has the field which inclined in the direction of arbitration in less than 3 times from this field as a slant face, and forming said compound semiconductor layer on said slant face.
[Claim 2] In the semiconductor device which has the compound semiconductor layer expressed with a general formula (however, x+y+z=1, 0<=x<=1, 0<=y<=1, 0<=z<=1) InxGayAlzN the field where said compound semiconductor layer rotated the field (100) 7.3 degrees around [01-1] shaft -- or It is the semiconductor device which it is formed using the silicon substrate which has the principal plane which consists of fields in the range leaned in the direction of arbitration in 3 times with from this field, and said silicon substrate is equipped with the slot which has a field (111) as a slant face, and is characterized by forming said compound semiconductor layer on said slant face.
[Claim 3] The <0001> directions of said compound semiconductor layer are semiconductor devices according to claim 1 or 2 characterized by being an abbreviation perpendicular on said slant face.
[Claim 4] Said compound semiconductor layer is a semiconductor device according to claim 1 or 2 characterized by having a field (1-101) as field bearing.
[Claim 5] This luminous layer is a semiconductor device according to claim 4 characterized by for said semiconductor device being a semi-conductor light emitting device which has a luminous layer, and said compound semiconductor layer having a field (1-101) as field bearing including said luminous layer.
[Claim 6] To the principal plane of a silicon substrate, from this principal plane, in the sloping field of 62 degrees Or the process which forms the slot which has the field which inclined in the direction of arbitration in less than 3 times from this field as a slant face, The manufacture approach of a semiconductor device equipped with the process which forms the compound semiconductor layer expressed with a general formula (however, x+y+z=1, 0<=x<=1, 0<=y<=1, 0<=z<=1) InxGayAlzN on said slant face.

[Claim 7] (100) To said principal plane of the silicon substrate which has the principal plane constituted in the field which exists within limits leaned in the direction of arbitration in 3 times with, from the field which rotated the field 7.3 degrees around [01-1] shaft, or this field (111) The manufacture approach of a semiconductor device

equipped with the process which forms the slot which has a field as a slant face, and the process which forms the compound semiconductor layer expressed with a general formula (however, x+y+z=1, 0<=x<=1, 0<=y<=1, 0<=z<=1) AlxGayInzN on said slant face.

[Claim 8] Said slot is the manufacture approach of the semiconductor device according to claim 6 or 7 characterized by making said compound semiconductor layer which it came to prepare and was formed from the slant face of each of said slot on Si substrate coalesce according to crystal growth. [two or more]
[Claim 9] The manufacture approach of the semiconductor device according to claim 8 characterized by having the process which removes said silicon substrate after said compound semiconductor stratification.
[Claim 10] To the principal plane of a silicon substrate, from this principal plane, in the sloping field of 62 degrees Or the process which forms two or more slots which have the field which inclined in the direction of arbitration in less than 3 times from this field as a slant face, The process which forms the compound semiconductor crystal expressed with a general formula (however, x+y+z=1, 0<=x<=1, 0<=y<=1, 0<=z<=1) InxGayAlzN on said slant face, By growing up further and making the formed compound semiconductor crystal coalesce from the slant face of each of said slot The manufacture approach of the semi-conductor substrate equipped with the process which obtains the semi-conductor substrate which removes said silicon substrate and serves as a process which obtains the compound semiconductor crystal of the shape of continuous film from this compound semiconductor crystal after obtaining the compound semiconductor crystal of the shape of said film.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] In a nitride system semiconductor device, the substrate which rotated 7.3**3 times around [01-1] shaft from the silicon substrate (001) side is used for this invention. A slot with the field (111) of silicon is formed with an etching technique, and the semi-conductor film is related with the production approach of the nitride system semiconductor device characterized by having a field (1-101) as field bearing, and its substrate by performing crystal growth of the nitride semi-conductor film to the slot.
[0002]

[Description of the Prior Art] The light emitting device which used the InxGa1-xN crystal as a luminous layer on silicon on sapphire, the GaN substrate, the SiC substrate, or the silicon (111) substrate is produced until now using the nitride semiconductor material which consists of GaN, InN, AlN(s), and those mixed-crystal semiconductors. It is hoped that Si substrate may be able to manufacture the above-mentioned light emitting device by low cost by adopting this especially since what quality fixed by the large area as compared with other substrates is obtained cheaply.
[0003]
[Problem(s) to be Solved by the Invention] However, although the nitride semi-conductor film which has C side as a growth side was obtained using the silicon (111) substrate when the nitride semi-conductor was grown up, this epitaxial semi-conductor film did not have so good the surface smoothness in atomic level.
[0004] For example, when the laminating of the cladding layer of n mold, the luminous layer which consists of InxGa1-xN of a quantum well mold, and the cladding layer of p mold was carried out on these substrates and the semiconductor device of the fine structure was produced, from the effect which membranous non-surface smoothness has, since the thickness of a luminous layer and the ununiformity of In presentation arose, the luminescence was affected, and only the semi-conductor light emitting device which has an emission spectrum with wide 40nm and half-value width was obtained. Moreover, only that in which the optical output of such a light emitting device is inferior as compared with the component on silicon on sapphire or a SiC substrate was obtained.
[0005] On the film which produced by growing up the GaN layer which performed Si dope through the high resistive layer which consists of an AlGaN layer using these substrates, moreover, the source, The GaN system MESFET which produced the drain and the electrode which consists of the gate (Metal semiconductor Field effect transistor) Also in the GaN system MODFET (Modulation dope Field effect transistor) which furthermore performed the modulation dope of Si on the GaN channel layer the surface smoothness from a low reason Since the steepness of a channel layer interface was scarce, by concavo-convex dispersion, the mobility of the electron which runs in a channel layer fell, and the good semiconductor device of electrical characteristics was not obtained with the cut-off frequency etc.
[0006] This invention solves the above-mentioned technical problem. Namely, in the laminated structure of a nitride system semi-conductor, in order that this invention may raise raising and the photoelectrical property of a component with improving surface smoothness in atomic level for steepness, using a silicon substrate, it is quality and aims at offering the crystal growth of the nitride epitaxial film which was excellent in surface smoothness.
[0007]
[Means for Solving the Problem] The semiconductor device concerning this invention on one aspect of affairs The general formula InxGayAlzN formed on the principal plane of a silicon substrate and a silicon substrate It is the semiconductor device which has the compound semiconductor layer expressed with (x+y+z=1, 0<=x<=1, 0<=y<=1, 0<=z<=1). A silicon substrate [however,] the principal plane of this silicon substrate -- the sloping field of 62 degrees -- or it has the slot which has the field which inclined in the direction of arbitration in less than 3 times from this field as a slant face, and said compound semiconductor layer is formed on said slant face.
[0008] On other aspects of affairs, the semiconductor device concerning this invention A general formula InxGayAlzN It is the semiconductor device which has the compound

semiconductor layer expressed with (x+y+z=1, 0<=x<=1, 0<=y<=1, 0<=z<=1). [however,] the field where the compound semiconductor layer rotated the field (100) 7.3 degrees around [01-1] shaft -- or It is formed using the silicon substrate which has the principal plane which consists of fields in the range leaned in the direction of arbitration in 3 times with from this field, and the above-mentioned silicon substrate is equipped with the slot which has a field (111) as a slant face, and a compound semiconductor layer is formed on the above-mentioned slant face.

[0009] The <0001> directions of the above-mentioned compound semiconductor layer are abbreviation perpendiculars on said slant face. Moreover, a compound semiconductor layer has a field (1-101) as field bearing. In addition, it is shown that field bearing of the principal plane of a compound semiconductor layer is a field substantially (1-101) as having a field (1-101) as field bearing.

[0010] Moreover, the above-mentioned semiconductor device is a semi-conductor light emitting device which has a luminous layer (barrier layer), and, in the above-mentioned compound semiconductor layer, this luminous layer (barrier layer) has a field (1-101) as field bearing including this luminous layer (barrier layer).

[0011] The manufacture approach of the semiconductor device concerning this invention is equipped with each following process on one aspect of affairs. the principal plane of a silicon substrate -- this principal plane -- the sloping field of 62 degrees -- or the slot which has the field which inclined in the direction of arbitration in less than 3 times from this field as a slant face is formed. The compound semiconductor layer expressed with a general formula (however, x+y+z=1, 0<=x<=1, 0<=y<=1, 0<=z<=1) InxGayAlzN is formed on this slant face.

[0012] The manufacture approach of the semiconductor device concerning this invention is equipped with each following process on other aspects of affairs. (100) Form the slot which has a field (111) as a slant face in the principal plane of a silicon substrate which has the principal plane constituted in the field which exists within limits leaned in the direction of arbitration in 3 times with from the field which rotated the field 7.3 degrees around [01-1] shaft, or this field. The compound semiconductor layer expressed with a general formula (however, x+y+z=1, 0<=x<=1, 0<=y<=1, 0<=z<=1) AlxGayInzN is formed on this slant face.

[0013] The above-mentioned slot may make the compound semiconductor layer which it came to prepare and was formed from the slant face of each of said slot on Si substrate coalesce according to crystal growth. [two or more]

[0014] After the above-mentioned compound semiconductor stratification, you may have the process which removes a silicon substrate.

[0015] The manufacture approach of the semi-conductor substrate concerning this invention from this principal plane in the sloping field of 62 degrees to the principal plane of a silicon substrate Or the process which forms two or more slots which have the field which inclined in the direction of arbitration in less than 3 times from this field as a slant face, The process which forms the compound semiconductor crystal expressed with a general formula (however, x+y+z=1, 0<=x<=1, 0<=y<=1, 0<=z<=1) InxGayAlzN on this slant face, After obtaining the process which obtains the compound semiconductor crystal of the shape of film which continued by growing up further and making the formed compound semiconductor crystal coalesce from the slant face of each slot, and the compound semiconductor crystal of the shape of this film, a silicon substrate is removed and it has the process which obtains the semi-conductor substrate which consists of this compound semiconductor crystal.

[0016] GaN is the strong crystal of a stacking tendency, by the usual approach, c axis

orientation is carried out at right angles to a principal plane, and that to which the crystal therefore obtained makes C side a principal plane is obtained. It was difficult to obtain the crystal which has a different field from C side.

[0017] then -- for example, the substrate which rotated 7.3 degrees around [01-1] shaft from the silicon substrate (001) side -- or By etching to a part for opening without the mask which gives the mask by SiO252 selectively and consists of that SiO252 to the field which inclined in the direction of arbitration in less than 3 times from this field This off substrate (principal plane) 60 to 62 relation (111) By forming a slot with the facet side 61 and making that field carry out epitaxial growth of the nitride system semi-conductor film The facet (1-101) side 70 of a GaN system semi-conductor was made into the growth side, and it was drawn from much experiments of this invention person that growth is performed.

[0018] This facet side 70 is a field which was extremely excellent in surface smoothness, and the high nitride semi-conductor film of surface smoothness was obtained in atomic level by growing up using this substrate.

[0019] Since the coefficient-of-thermal-expansion difference between a silicon substrate and this substrate becomes small by furthermore leaning the c axis of the GaN film in this case, When the crack stopped being able to enter easily and the facet (1-101) side 70 is used as a growth side of a semi-conductor light emitting device in this way, In order that the electric field produced according to a piezoelectric effect in the well and barrier layer interface in a barrier layer might decrease by leaning C shaft and the carrier recombination probability of an electron-hole pair might increase, the result which luminous efficiency goes up was obtained.

[0020] Then, the semi-conductor light emitting device which becomes the shape of that semi-conductor film from an AlGaInN system nitride semi-conductor was produced using this film, and that property was measured. Consequently, also in the barrier layer, surface smoothness was very high, and since there was little fluctuation of the thickness, in the emission spectrum, the half-value width of 15nm and a narrow semi-conductor light emitting device were obtained.

[0021]

[Embodiment of the Invention] It explains the gestalt of operation being shown below about this invention.

[0022] A conceptual diagram for <gestalt 1 of operation> drawing 1 to form the facet (1-101) side 70 of the nitride semi-conductor film in the gestalt of this operation and drawing 2 are the outline sectional views showing the structure of this nitride semi-conductor light emitting device. The nitride semi-conductor light emitting device of the gestalt of this operation on the 7.3-degree(001) Si off substrate 1 to the [0-1-1] direction By etching to a part without the mask which gives the mask by SiO252 selectively and consists of the SiO252 This off substrate (principal plane) 60 to 62 relation (111) A slot with the facet side 61 is formed. The n-AlGaInN layer 10 by which flattening is carried out one by one as the following explanation from the facet side 61, and the laminating is carried out, the first cladding layer 2 which consists of n-GaInN, the luminous layer 3 which consists of InxGa1-xN, the carrier block layer 4 which consists of p-AlGaInN, It has the structure where the laminating of the second cladding layer 5 which consists of p-GaInN was carried out to order. Furthermore, an electrode 15 is formed in a silicon substrate underside, a transparent electrode 16 is formed in the top face of the second cladding layer 5, and the bonding electrode 17 is formed in a part of top face of a transparent electrode 16. In addition, the structure of SiO2 mask 52, a slot, etc. is omitted in drawing 2 .

[0023] Although the InxGa1-xN luminous layer could make the wavelength of luminescence between bands emit light from ultraviolet to red by changing the presentation x of GaxIn1-xN, with the gestalt of this operation, it was blue and it was taken as the thing which the presentation of the solid phase of Ga becomes from X= 0.82 and which emits light. Magnesium is doped and the second cladding layer 5 of p conduction type has strong resistance. Therefore, even if it pours in a current, i.e., an electron hole, only from the bonding electrode 17 to the end of the second cladding layer 5, there is a possibility that current density may not serve as homogeneity in the whole region of a luminous layer 3. Then, between an electrode 17 and the second cladding layer 5, the transparent electrode 16 of the thin film almost covering the whole surface of the second cladding layer 5 is formed, and many luminescence can be taken out from this part. It is [that what is necessary is just to use a metal for the electrode 15 connected on the silicon substrate of n conduction type] desirable to include whether they are aluminum, Ti, Zr, Hf, V, Nb, and ********. It is [that what is necessary is just to use the metal of thickness 20nm or less for the transparent electrode 16 connected to the second cladding layer 5 of GaN of p conduction type] desirable to include Ta, Co, Rh, nickel, Pd, Pt, Cu, Ag, or Au.

[0024] Next, it explains, also referring to drawing 1 about the manufacture approach of the light emitting device of this operation gestalt. First, a silicon substrate is washed, a spatter or the technique of CVD is used and silicon oxide or 100nm of silicon nitrides 52 are made to deposit on it. Then, silicon oxide or a silicon nitride is selectively removed in the shape of a stripe by performing the technique of photograph RISOGURAFU. Furthermore, the slot which has Si (111) facet side 61 for the wafer by acid etching, such as buffered fluoric acid, etc. is formed. This slot is a slot of the shape of a stripe extended in the direction of Si [01-1]. Since the principal plane 60 of a silicon substrate was made into the above-mentioned predetermined field bearing, the facet (111) side 61 was what has 62 relation to this, as shown in drawing 1 . This field can be easily formed by adjusting suitably the temperature of acid etchant known conventionally, and adjusting an etch rate suitably. Moreover, using the etchant of alkali, such as KOH, can also form easily. Moreover, in order to make the crystal growth from the above-mentioned predetermined facet (111) side 61 perform preferentially on a slot and Si substrate front face, as for the field except this being exposed, it is desirable that it carries out a mask that a nitride semi-conductor grows on [of a silicon nitride, a silicon oxide, etc.] it with an ingredient which is controlled.

[0025] and the substrate top -- MOCVD (organic metal chemical vapor deposition) -- the nitride semi-conductor film is grown up on the following growth conditions using law.

[0026] To the facet side 61 which has 62 relation from a silicon substrate, crystal growth advances considering a vertical shaft as c axis of the nitride semi-conductor film, and the facet (1-101) side of the nitride semi-conductor film is further formed as a flat surface 70 as it is shown in drawing 3 , when this substrate is used.

[0027] The silicon substrate used here was leaned in the direction of 7.3 degree [0-1-1] from the field (001), namely, (001) a flat surface 70 can have the almost same field bearing as the principal plane 60 of a silicon substrate from this with the principal plane 60 which rotated 7.3 degrees around [01-1] shaft from the field. Also when having inclined in the direction of arbitration in less than 3 times from this field, the very flat GaN side which has a field substantially (1-101) was acquired. Although the nitride semi-conductor film may be grown up to be only Mizogami and light emitting device structure may be formed after the facet (1-101) side 70 top of the nitride semi-

conductor film like drawing 1 , when growth of the nitride semi-conductor film is continued further, it is also possible for crystal growth to advance gradually from the left figure in drawing 3 , as shown in the right figure, and to form a semi-conductor light emitting device on the made continuation film. With the gestalt of this operation, the component was formed on the continuation film which carried out in this way and was obtained.

[0028] First, according to the process described above, the silicon substrate 1 in which the slot was formed is introduced in an MOCVD system, and it cleans at about 1100-degree C elevated temperature in a hydrogen (H2) ambient atmosphere.

[0029] then -- as carrier gas -- N2 -- a 10 l/min. sink ****** -- 800 degrees C -- NH3, trimethyl aluminum (TMA) and trimethyl in JUUMU (TMI), and SiH4 (silane) gas -- respectively -- 5l/min. and 10micromol/min. -- 17micromol/min.0.1micromol/min. installation of is done and silicon dope aluminum0.85In0.15N layer 10 [with a thickness of about 10nm] is grown up.

[0030] then, the same temperature -- supply of TMA -- stopping -- trimethyl GARYUUMU (TMG), TMI, and SiH4 (silane) gas -- about 20micromol/min., 100micromol/min., and 0.05micromol/min. -- it introduces, respectively and the first cladding layer 2 with a thickness of about 3 microns of silicon dope Ga0.92In0.08N is grown up.

[0031] Of this, a slot is filled, the first cladding layer 2 of Ga0.92In0.08N which adjoins further is connected, respectively, and the first cladding layer 2 of Ga0.92In0.08N which has the flat (1-101) field 70 is formed on Si substrate.

[0032] Although this first cladding layer 2 did not care about that growth temperature as film of raising and GaN at an elevated temperature after depositing said AlInN interlayer 10, it was using the GaInN cladding layer which does not contain aluminum including In, and low dental-curing length became possible, without raising growth temperature to an elevated temperature, and there was little generating of a crack in this case.

[0033] then, supply of TMA, TMI, and TMG is suspended, the until temperature fall of the substrate temperature is carried out to 760 degrees C, and the well layer of 3nm thickness which does 2.8micromol/min. installation of the trimethylindium (TMI) which is an indium raw material, and consists 6.5micromol/min. and TMG of In0.18Ga0.82N in it is grown up. The barrier layer which carries out temperature up to 850 degrees C, does 14micromol/min. installation of TMG, and consists of GaN is grown up again after that. Growth of a well layer and a barrier layer is repeated similarly, and the luminous layer 3 which consists of a multiplex quantum well (MQW) which consists of four pairs is grown up.

[0034] After growth of the above-mentioned luminous layer is completed, the p mold aluminum0.20Ga0.75In0.05N carrier block layer 4 of a 10 nmol/min. sink and 50nm thickness is grown up [magnesium / which is / TMG / 40micromol/min.p mold doping material gas about 1.1micromol/min. and TMI in 11micromol/min. and TMA / bis (cyclopentadienyl)] in (Cp2Mg) at the same temperature as the last barrier layer. After growth of the carrier block layer 4 is completed, in the same growth temperature, supply of TMA is suspended, the second cladding layer 5 of p mold Ga0.9In0.1N of 80nm thickness is grown up, and growth of light emitting device structure is ended. After growth is completed, and suspending supply of TMG, TMI, and Cp2Mg, it cools to a room temperature and takes out from an MOCVD system. Then, on the top face of the second cladding layer which consists of a p mold Ga0.9In0.1N layer, further, the bonding electrode 17 is formed in the part on it, an electrode 16 is formed

substrate underside, and the light emitting device of the gestalt of this operation completes a transparent electrode 16.
[0035] And the property of the produced semiconductor device was measured. Consequently, also in the barrier layer, surface smoothness was very high, and since there was little fluctuation of the thickness, in the emission spectrum, the half-value width of 15nm and a narrow semi-conductor light emitting device were obtained. Moreover, the luminescence reinforcement was 10 or more times as compared with the component formed on Si (111) substrate which is the conventional technique.
[0036] In the gestalt 1 of the <gestalt 2 of operation> operation, although direct light emitting device structure was produced on the silicon substrate leaned 7.3 degrees from the field (001), it was also possible to have produced a semiconductor device using the flat GaN substrate obtained by removing silicon, using this silicon off substrate as a substrate substrate for GaN substrate production.
[0037] MOCVD (organic metal vapor growth) -- using law, on this Si off substrate, an AlN interlayer is once used and GaN is grown up. However, the same result was obtained even if this interlayer used AlInN and an AlGaN interlayer.
[0038] The substrate is introduced in HVPE (hydride VPE) equipment. Temperature up of the temperature of a substrate is carried out for NH3 to N2 carrier gas to about 1050 degrees C with 5l. / min. sink, respectively. Then, 100 cc/min. installation of GaCl is done on a substrate, and growth of the thick film of GaN is started. GaCl is generated by passing HCl gas to Ga metal held at about 850 degrees C. Moreover, by passing impurity gas using the impurity doping line piped independently to near the substrate, while growing up to be arbitration, an impurity can be doped. In this example, while starting growth in order to dope Si, 200 nmol/min. supply (Si high-impurity-concentration [of about 3.8x1018cm] - 3) of a mono silane (SiH4) was done, and the Si dope GaN film was grown up.
[0039] By the above-mentioned approach, growth of 8 hours was performed and the sum total of thickness grew GaN with a thickness of about 350 micrometers on Si substrate. Polish or etching removes Si substrate after growth, and the very flat GaN substrate which has a field (1-101) is obtained. In this way, according to the gestalt of this operation, the GaN substrate which has a field (1-101) on a front face can be obtained.
[0040] And after introducing this washed GaN substrate of this in an MOCVD system, temperature up of the substrate temperature is carried out to 760 degrees C on a GaN substrate, and the well layer of 3nm thickness which does 2.8micromol/min. installation of the trimethylindium (TMI) which is an indium raw material, and consists 6.5micromol/min. and TMG of In0.18Ga0.72N in it is grown up. The barrier layer which carries out temperature up to 850 degrees C, does 14micromol/min. installation of TMG, and consists of GaN is grown up again after that. Growth of a well layer and a barrier layer is repeated similarly, and the luminous layer 3 which consists of a multiplex quantum well (MQW) which consists of four pairs is grown up.
[0041] After growth of the above-mentioned luminous layer is completed, the p mold aluminum0.20Ga0.75In0.05N carrier block layer 4 of a 10 nmol/min. sink and 50nm thickness is grown up [magnesium / which is / TMG / 40micromol/min.p mold doping material gas about 1.1micromol/min. and TMI in 11micromol/min. and TMA / bis (cyclopentadienyl)] in (Cp2Mg) at the same temperature as the last barrier layer. After growth of the carrier block layer 4 is completed, in the same growth temperature, supply of TMA is suspended, the second cladding layer 5 of p mold Ga0.9In0.1N of 80nm thickness is grown up, and growth of light emitting device structure is ended.

After growth is completed, and suspending supply of TMG, TMI, and Cp2Mg, it cools to a room temperature and takes out from an MOCVD system. Then, on the top face of the second cladding layer which consists of a p mold Ga0.9In0.1N layer, further, the bonding electrode 17 was formed in the part on it, the electrode 15 was formed in the GaN substrate underside for the transparent electrode 16, and the light emitting device of the gestalt of this operation was produced.

[0042] Like the above, the half-value width of 15nm and a narrow semi-conductor light emitting device were obtained in the emission spectrum by producing the very flat GaN substrate which has a field (1-101) 70 by using Si substrate as a start substrate, and producing a semiconductor device after that. Moreover, the luminescence reinforcement of the light emitting device obtained in this way was further 3 or more times of the component of the gestalt 1 of operation, and was the thing of high brightness very much.

[0043] although light emitting device structure using the vapor growth which used the organic metal in the gestalt 1 of the <gestalt 3 of operation> operation on the silicon substrate leaned 7.3 degrees from the field (001) was produced -- molecular beam epitaxy (MBE) -- having produced with the grown method by law was also possible. With the gestalt of this operation, the MOCVD growth process of the gestalt 1 of operation was changed into the following MBE growth processes.

[0044] As Ga, aluminum, and the In source, Metals Ga, aluminum, and In were used, respectively. Moreover, NH3 was used as the source of N.

[0045] The washed silicon substrate 1 is introduced in MBE equipment, and it cleans at about 1100-degree C elevated temperature among a high vacuum.

[0046] Then, NH3 and Metals aluminum and In are introduced at 800 degrees C, and aluminum0.85In0.15N layer 10 [with a thickness of about 20nm] is grown up.

[0047] Then, at the same temperature, supply of Metal aluminum is suspended, Metals Ga and In are introduced, respectively, and the first cladding layer 2 with a thickness of about 300nm of silicon dope Ga0.92In0.08N is grown up.

[0048] then, after suspending Metals aluminum and In and Ga supply and carrying out the until temperature fall of the substrate temperature to 760 degrees C, the luminous layer 3 which consists of a multiplex quantum well (MQW) is grown up.

[0049] After growth of the above-mentioned luminous layer is completed, at the same temperature as the last barrier layer, Mg which is Metals aluminum and In and p mold doping material gas about Metal Ga is introduced, and the p mold aluminum0.20Ga0.75In0.05N carrier block layer 4 of 50nm thickness is grown up. After growth of the carrier block layer 4 is completed, in the same growth temperature, supply of Metal aluminum is suspended, the second cladding layer 5 of p mold Ga0.9In0.1N of 80nm thickness is grown up, and growth of light emitting device structure is ended. As mentioned above, after the MBE method, on the top face of the second cladding layer which consists of a p mold Ga0.9In0.1N layer, further, the bonding electrode 17 is formed in the part on it, an electrode 15 is formed in Si substrate underside, and the light emitting device of the gestalt of this operation completes a transparent electrode 16.

[0050] With the gestalt 1 of the <gestalt 4 of operation> operation, Si (111) side used the property easily formed by the etching approach (wet etching) which used etchant, and had obtained the slot slant face which inclined about 62 degrees from the silicon principal plane. In this way, the obtained slant face is the so-called crystal facet, process tolerance is not only stable, but is excellent in surface smoothness, and excellent as a substrate of growing up a nitride semi-conductor. However, the

applicability of this invention is not restricted only to this. It not only uses the silicon substrate leaned 7.3 degrees from the field (001) as a principal plane, but in other fields, like the gestalt 1 of the operation to a silicon principal plane, it gave the mask 52 selectively and it became possible from much experiments of an artificer to form the dip slot which consists of 62 degrees to a principal plane by change the temperature of etching, and a rate further.

[0051] Then, the same result was obtained when it inquired using the field. That is, crystal growth to which a GaN (1-101) side is parallel mostly with a substrate principal plane was possible like the gestalt 1 of operation, and as a result of continuing such growth, the continuous crystal film which has a flat GaN (1-101) side in a front face was obtained. Although it was difficult to obtain the crystal which has a field which GaN is the strong crystal of a stacking tendency, and carries out c axis orientation at right angles to a principal plane by the usual approach, and only that to which the crystal therefore obtained makes C side a principal plane is obtained, but is different from C side, the crystal which has a GaN (1-101) side in a front face came to be easily obtained by this invention.

[0052] It explains still more concretely about the manufacture approach of the semiconductor device of <gestalt 5 operation> this invention.

[0053] (001) From a field, as drawing 4 , it has film production techniques, such as a spatter, and a stripe [which was further extended in the direction of Si [01-1] using the technique of photolithography]-like pattern, and form the mask 52 with a thickness of 100nm it is thin from the silicon oxide or the silicon nitride for facet formation in the leaned silicon substrate which was turned off 7.3 degrees in the [0-1-1] direction. Then, etching formation of the slot which has the facet (111) side 61 on a slant face with the diluted KOH water solution is carried out as drawing 5 . At this time, the configuration of a slot itself has the configurations of deformation where the field of V characters or a bottom is flat, such as V etc. characters, and another slant face turns into a facet (1-1-1) side. In addition, although the configuration of V characters is not bilateral symmetry but the field where about 62 degrees (111) of slant faces inclined to the substrate principal plane since a silicon substrate is an off substrate, a slant face (1-1-1) is a field which inclined the said about 47 degrees. A film is produced, and the mask 52 which consists of silicon oxide or a silicon nitride is given so that a facet (1-1-1) side may also be covered, and it carries out as drawing 6 so that the film may not reach the facet (111) side 61 by installing this substrate in the condition of having leaned within the sputtering system. Let this be a substrate for nitride semi-conductor film creation. Si substrate in this case and the orientation relationship of a facet side etc. were shown in drawing 8 .

[0054] And it grows up by using the MOCVD method for Si substrate which went this processing. By growing up an AlInN interlayer and growing up GaN continuously on this Si OFF substrate, it passes like a growth fault like drawing 7 (a) - (d), and it becomes possible to produce the GaN substrate which consists of continuation film. Crystal growth starts crystal growth from on a facet (111) (a). The <0001> directions carry out orientation of the nitride semi-conductor which grows vertically to a slant face. It becomes the crystal of a configuration like the triangle pole which the GaN (1-101) side appeared in parallel mostly at the substrate principal plane, therefore was extended in the direction of a stripe in the phase in the middle of growth on the top face of the grown-up crystal (b). furthermore, growth progresses -- alike -- following -- the path of the triangle pole -- large -- becoming -- just -- being alike -- (c) which adjoining triangle pole-like crystals come to contact. Furthermore, when growth is

continued, the separated three angle each columnar crystal will coalesce, and the GaN crystal film which had a flat GaN (1-101) side in the front face will be obtained (d).

[0055] The same result was obtained even if it used the AlInN interlayer, the AlGaN interlayer, and the AlGaInN interlayer as this interlayer that used in early stages of growth.

[0056] Although the facet (111) side was here used as a slant face which inclined 62 degrees from the principal plane using the above-mentioned necessary field (001) silicon-off substrate, Si facet side which consists of (211) can also be formed by etching instead of (111) by controlling the etchant concentration of KOH, and temperature. In this case, the facet (211) side could be formed in the [100] directions from the field (2-1-1) as a slant face which inclined 62 degrees from the principal plane by creating the stripe-like slot extended in the [01-1] direction on the silicon substrate turned off 8.6 degrees, and the GaN crystal film with the same flat front face as the above was obtained by this.

[0057] A nitride semiconducting crystal makes vertical axes c axis also to this (211) facet side, growth is performed, and this is using Si off substrate which has relation with an include angle of 62 degrees from a field (211) also in this case, and is considered that the same flat GaN substrate is obtained.

[0058] Thus, by this invention, when Si substrate is used, the crystal growth of c axis orientation is easy to be performed to a substrate, and the nitride semi-conductor film can use the crystal film with the facet (1-101) side of a flat nitride semi-conductor by using the substrate with which the relation of the OFF angle of a facet and a substrate consists of 62 degrees.

[0059] Thus, it became producible [the semi-conductor light emitting device of the high brightness to Si substrate top] by forming the semi-conductor light emitting device as drawing 2 like the gestalt 1 of operation on the nitride semi-conductor film which consists of obtained continuation film. In this way, as for the obtained semi-conductor light emitting device, the luminous layer (barrier layer) has the field (1-101) as a principal plane. This differs from the component currently formed using silicon on sapphire, the SiC substrate, and Si (111) substrate having made (0001) the principal plane conventionally. Although the thin film which made the principal plane (0001) of the nitride semi-conductor which is a wurtzite structure crystal is equivalent in band structure in a direction parallel to the principal plane, the direction parallel to the principal plane of the thin film which made the field the principal plane like this invention (1-101) is not equivalent in band structure, either. Therefore, degeneration of the band of a direction parallel to a luminous layer (barrier layer) has solved the light emitting device adapting this invention, and luminous efficiency is high, and when it applies to a semiconductor laser component, a marked low threshold can be realized.

[0060] Although it passed even like the growth fault shown in drawing 7 (d), the nitride semi-conductor film which consists of continuation film was formed in the gestalt 5 of the <gestalt 6 of operation> operation and the semi-conductor light emitting device was produced on it As a growth fault finishes the crystal growth of each nitride semi-conductor layer in the gestalt of this example in the condition that the crystalline of the process of (b), i.e., each triangle pole configuration, does not coalesce from (a) and it is shown as drawing 9 It makes it possible to form a semi-conductor light emitting device in the crystalline of each triangle pole configuration separately, and to make a light emitting device emit light according to an individual.

[0061] It has the structure where the laminating of the n-AlGaInN interlayer 10 and the n-GaN substrate layer 11 by which the laminating was carried out one by one to the

facet side 61 formed on Si substrate as a configuration of a component, the first cladding layer 2 which consists of n-GaInN, the luminous layer 3 which consists of InxGa1-xN, the carrier block layer 4 which consists of p-AlGaInN, and the second cladding layer 5 which consists of p-GaInN was carried out to order. Furthermore, an electrode 15 is formed in a silicon substrate underside, a transparent electrode 16 is formed in the top face of the second cladding layer 5, and the bonding electrode 17 is formed in a part of top face of a transparent electrode 16.

[0062] Although the gestalt 1 of the <gestalt 7 of operation> operation thru/or explanation of 4 explained growing up a nitride semi-conductor only into the slant face of one side of the stripe slot established in Si substrate With the gestalt of this operation, each semi-conductor light emitting device was formed in Si slant face of both sides like explanation of the gestalt 6 of operation as the slant face of both sides was formed as what has the predetermined OFF include angle of a principal plane and it was shown in drawing 10 .

[0063] Although the gestalt of the above-mentioned implementation mainly took up and explained the semi-conductor light emitting device which is LED as a semiconductor device The applicability of this invention is not restricted to this, and may be applied to a semiconductor laser component. On the film which produced by growing up the GaN layer which performed Si dope through the high resistive layer which consists of an AlGaN layer using the above-mentioned technique, moreover, the source, The GaN system MESFET which produced the drain and the electrode which consists of the gate (Metalsemiconductor Field effect transistor) Are applicable to the GaN system MODFET (Modulation dope Field effect transistor) which furthermore performed the modulation dope of Si on the GaN channel layer. Since the surface smoothness of each class can be improved in these, the steepness of a channel layer interface is good. While being able to realize improvement in the mobility of the electron which runs in the channel layer by concavo-convex dispersion and obtaining the good semiconductor device of electrical characteristics with the cut-off frequency etc. Since the conductivity between nitride semi-conductor layers with Si substrate is securable, a component can be formed also on Si substrate at one, and the integrated semiconductor device circuit can be manufactured.

[0064] Although the gestalt of operation of this invention was explained as mentioned above, it should be thought that the gestalt of the operation indicated this time is [no] instantiation at points, and restrictive. The range of this invention is shown by the claim and all modification in a claim, equal semantics, and within the limits is included.

[0065]

[Effect of the Invention] According to this invention, it is related with the nitride semiconductor device produced on a silicon substrate. the field which inclined 62 degrees from the principal plane of a silicon substrate, and the field which rotated the silicon substrate (001) side 7.3 degrees around [01-1] shaft -- or By using the field which inclined in the direction of arbitration in less than 3 times from these fields (1-101) It became possible to obtain the very flat high quality crystal film which has an epitaxial side, and it became possible to offer the semiconductor device which has the outstanding photoelectrical property with a steep interface by using the epitaxial side.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is a conceptual diagram for forming the facet (1-101) side of the nitride semi-conductor film.
[Drawing 2] It is the sectional view showing the light emitting device of the gestalt of operation of this invention.
[Drawing 3] It is drawing showing the relation of the substrate nitride semi-conductor film used for this invention.
[Drawing 4] It is drawing for explaining the manufacture approach of the compound semiconductor of this invention.
[Drawing 5] It is drawing for explaining the manufacture approach of the compound semiconductor of this invention.
[Drawing 6] It is drawing for explaining the manufacture approach of the compound semiconductor of this invention.
[Drawing 7] It is drawing for explaining the manufacture approach of the compound semiconductor of this invention.
[Drawing 8] It is drawing for explaining the orientation relationship in Si substrate of the gestalt 5 of operation.
[Drawing 9] It is the sectional view showing the semi-conductor light emitting device of the gestalt 6 of operation.
[Drawing 10] It is the sectional view showing the semi-conductor light emitting device of the gestalt 7 of operation.
[Description of Notations]
1 Si (001) Off Substrate, 2 First Cladding Layer Which Consists of N-GaInN, 3 Non, a dope InGaN luminous layer, 4 p-AlGaIn carrier block layer, 5 The second cladding layer, 10 which consist of p-GaInN n-AlGaInN layer, 11 A GaN substrate layer, 15 An electrode, 16 A transparent electrode, 17 Bonding electrode, 52 A mask (silicon oxide or silicon nitride), 53 Nitride semiconducting crystal, 60 The field (001) of silicon, 61 The facet (111) side of silicon, 70 The facet (1-101) side of a nitride semi-conductor, 71 The facet (0001) side of a nitride semi-conductor, 72 The field (1-101) of the nitride semi-conductor which changed into the condition of the continuation film, 80 The c axis of a nitride semi-conductor, 81 Growth travelling direction of a nitride semi-conductor.

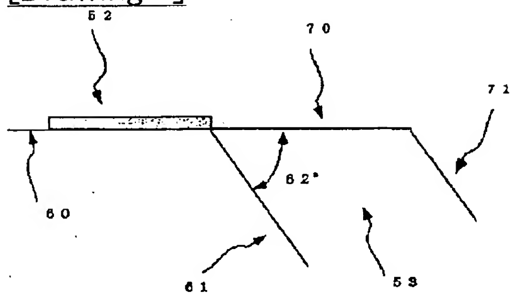
[Translation done.]

* NOTICES *

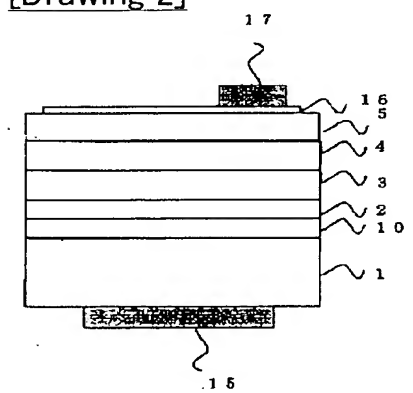
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

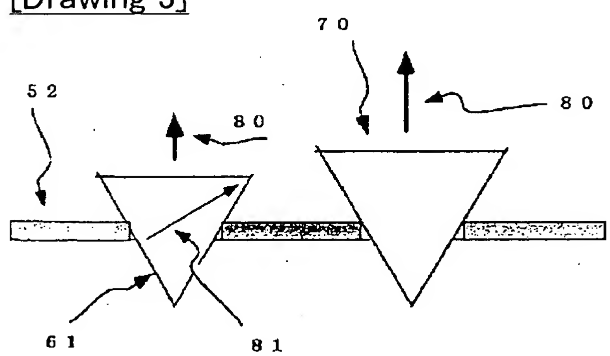
[Drawing 1]



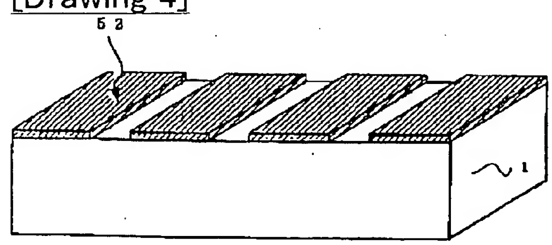
[Drawing 2]



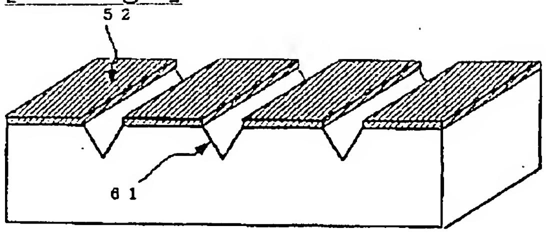
[Drawing 3]



[Drawing 4]



[Drawing 5]



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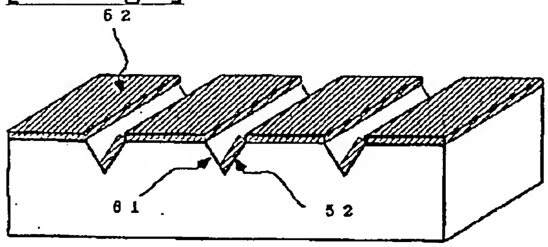

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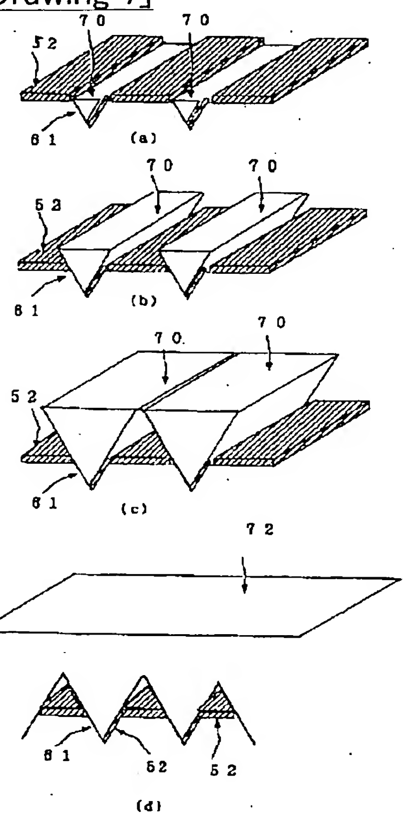
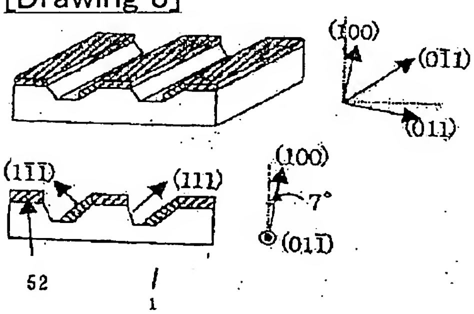
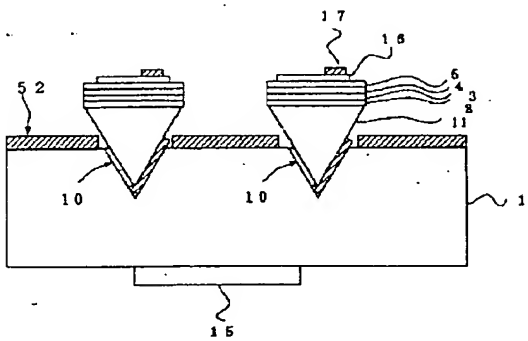


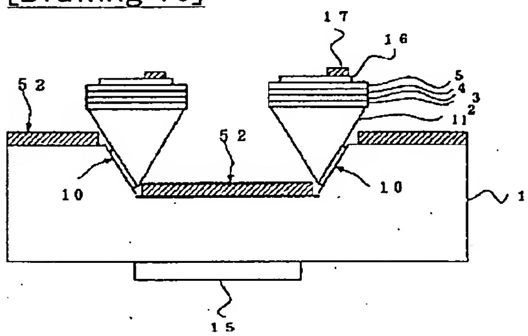
[Drawing 8]



[Drawing 9]



[Drawing 10]



[Translation done.]